At the same time we have seen that a similar result may be obtained by familiarity and practice. (iii) It is necessary, for determination of the limen of difference, to avoid knowledge of the actual relations of the distances compared on the part of the reagent (p. 159). This point has also been insisted on by Mr. Knox. (iv) Judgment should be as immediate as possible; since it is apt to fluctuate, if the stimulus is present for any length of time (p. 159). *Cf.* the length of Mr. Knox' experimental series (p. 414). The method employed both by Auerbach and ourselves being a form of minimal changes, the necessity of immediacy of judgment is a matter of course.

VIII.

The Cutaneous Estimation of Open and Filled Space.

By Professor C. S. Parrish.

A comparison of the spatial functioning of the cutaneous and visual sensibilities must always possess an especial psychophysical interest. The study of sensational intensities culminates in Weber's Law; that of sensational quality leads to a whole number of alternative psychophysical theories; the determination of the temporal attributes of sensation is one means of approaching the problems of the so-called time-sense; that of its spatial attributes, the first step towards a psychological space construction. But, whereas every sensation is possessed of duration, quality, and (with the exception of the visual series) intensity, a space attribute attaches exclusively to the sensations of sight and pressure. This fact, which seems at first sight to simplify the space problem, in reality renders that problem unusually difficult of solution.

Opinions differ very widely as regards the sensational factor in psychological space, as regards the interaction of eye and skin in its construction, and as regards the attributes and aspects of the cutaneous sensibility itself. It may, therefore, be well to give here, at the outset, a brief *credo*, not with any intention of dogmatizing, but merely with a view to clearness and intelligibility.

We believe, then, that the development of the eye, as a space organ, far outran that of the skin. That tactual space was, accordingly, built up under the influence of, and remains almost invariably subject to that of vision. Nevertheless, that there are two psychological spaces, and not one space. We consider, further, that the mechanical cutaneous sensi-

bility has *(pace* Dessoir) only one quality, that of pressure. That the cutaneous local signature is physiological only, although the retinal—as is indicated by many facts which cannot here be adduced—is psychological. And that in its ordinary functioning, the skin co-operates with the three deeper lying sensibilities, the tendinous (with its quality of strain), the articular (with its quality of pressure, and possibly with its own local signature), and the muscular (with its peculiar quality which only becomes seriously involved in fatigue or exhaustion). Finally, we ascribe to the cutaneous and visual sensation an attribute of extension, which we regard as co-ordinate with intensity, quality and duration, and which is by no means to be confused with the "bigness" or "massiveness" predicate of one school of nativistic psychologists.

After this preface we may approach the special problem which heads this paper. Almost unexceptionally, the eye regards a filled space as greater than an empty space objectively equal to it. What is the attitude of the skin to such spaces? It has recently been maintained that pressure *plus* movement functions, in this regard, as does the eye.[1] But one of the explanations propounded for the visual illusion is couched in terms of movement: it being argued that though the resting eye is also subject to the error, it is only so subject because, at some time or another, it has moved. The argument is paralleled by many others of the chapter of psychology which deals with visual perception, and need not be further commented on. Now, if the resting skin *(sit venia verbo!)* were deluded equally with the moving, then, although visualization might be called in to explain the fact, we should still be in presence of a phenomenon telling with more or less of force against the movement theory. If, however, the resting skin, in spite of visualization, and in spite of its own constant movement in the past, should prove to be not deluded, the movement theory is so far supported. Should the illusion be actually reversed, we must look for the conditions of such reversal in the special psychophysics of the organ.

The problem, then, resolves itself into that of obtaining comparative space judgments from the resting skin. If the skin, and the skin only, is to be appealed to, stimulation must be liminal. In this case, however, judgment will be uncertain, and comparison difficult. Since in ordinary life the static functioning of the skin is almost invariably correlated with a similar functioning of the deeper lying sensibilities—since, *i. e.*, normal stimulation is almost always supra-

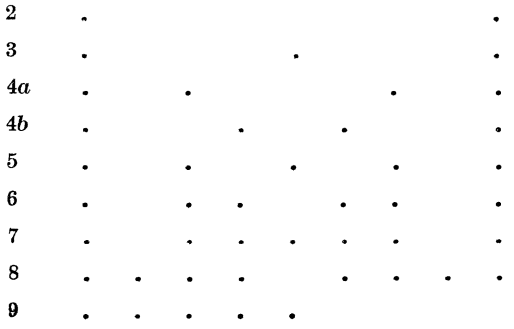
[1] Dresslar, this JOURNAL, pp. 332 ff. The view of this author is criticised below.

liminal—it seems needless to make an attempt to eliminate the latter. The problem can be solved, with equal accuracy, and with much greater facility, by the application of an ordinary æsthesiometrical pressure.

Our experiments, which fall into two groups, were carried out in the months July to September of the current year, upon seven subjects: Miss Bowman (*B.*), Miss Hunt (*H.*), Mrs. Oliver (*O.*), Mrs. Titchener (*T.*), and Professors Hammond (*Ha.*), Oliver (*Ol.*), and Titchener (*Ti.*). The part of the cutaneous surface worked upon was the skin of the internal side of the wrist and forearm, beginning from a point on the median line lying 1 cm. from the transverse wrinkles at the junction of the wrist and palm. All experiments were taken in the longitudinal direction, up the arm, and only the median surface was stimulated. No experimental series exceeded thirty minutes in duration: the time adhered to, with but very few exceptions, being twenty minutes.

SERIES I.

Apparatus.—Our apparatus consisted of nine oblong pieces of light wood, in each of which was fixed a definite number of points of hard rubber, 1 cm. long, turned at the extremity to a diameter of $\frac{1}{3}$ mm. (made by C. Krille, Leipzig). The distance between the extreme points was constant at 64 mm.; that between point and point, in the completely "filled" line, 8 mm.,—this line containing nine points. The blocks were used as æsthesiometers, constancy of pressure having to be learned by experience. So far as we know, this is the case with all æsthesiometers, with the exception of those of Jastrow and Washburn (this JOURNAL, p. 422.) The writer of the present paper was the only experimenter throughout. In the subjoined scheme we give a plan of the various blocks; the first vertical column telling the number of points in the block (which number we shall use, in what follows, to designate the block itself), and the dots to the right showing the arrangement of these points.



Method.—We imagined, at the outset of the investigation, that a very large number of experiments would be needed, if any satisfactory result was to be obtained. We therefore employed a modification of the method of right and wrong cases. Instead of taking too little-different stimuli, as that method requires, we proposed to compare each block with every other block, recording the judgments as *r*, *w*, = and ? [*r* being used on the optical analogy, when the cutaneous judgment made a filled larger than an objectively equal empty space]; while, to avoid *Einstellung*, we did not confine ourselves to one pair of blocks in each series of experiments, but intermixed the comparisons at random. But the uniformity of which we were in search made its appearance so quickly, decidedly and unmistakably, that this original plan was not carried out. We have, consequently, only a relatively small number of experiments taken by this method, and those we propose to submit in detail.

In the following Table the first column gives the blocks compared, the numbers (as stated above) signifying the number of points in each block; while in the others, each of which is accredited to a different reagent, the signs ($>$ or $<$) gives the judgment of relation recorded N times out of n experiments. Thus, "2 : 3 $>$ 4 6" means that the two-point distance was judged greater than the three-point distance four times out of six experiments, by the particular reagent. Of the seven subjects, one only, (*Ti.*) had had general as well as special practice. His results, although not numerous, are the most reliable. The other six reagents were specially practised for the purposes of this investigation. It should be stated that during the first half (approximately) of these experiments, the application of the second stimulus was not to the exact part of the skin stimulated by the first, but to a line just alongside of it; during the second half the successive applications were made at precisely the same place. Absolutely no difference in result could be discovered; and irradiation makes this intelligible. Both sets of experiments have, therefore, been drawn upon in the composition of the Table.

Remarks.—(1) We notice at once that, for the resting skin, *a filled distance is*, on the average, *shorter than an empty distance objectively equal to it.* This holds for every reagent. In the earlier stages of practice, when visualization was especially insistent, there occurred sporadic cases to the contrary effect: the filled distance appeared longer. But such cases disappeared as practice progressed; and introspection referred them very definitely to the influence of the visual idea.

TABLE I.

	B.		Ha.		H.		O.		Ol.		T.		Ti.	
	N	n	N	n	N	n	N	n	N	n	N	n	N	n
2 : 3	> 4	6	> 2	2	> 2	4	> 5	6	> 4	5	> 7	11	> 4	4
: 4a	" 5	6	< 4	5	" 7	13	" 1	2	" 5	6	" 5	8	" 2	2
: 4b	" 3	4	——		" 3	4	" 5	5	" 4	5	" 3	3	——	
: 5	" 4	6	> 5	6	" 4	6	" 5	7	" 3	5	" 5	7	" 5	6
: 6	" 3	4	" 3	3	" 4	6	" 4	4	" 3	3	" 4	6	" 2	2
: 7	" 2	4	" 3	4	" 3	4	" 4	4	" 2	3	" 9	10	" 2	2
: 8	" 4	6	" 1	2	" 5	5	" 6	7	" 5	5	" 3	4	——	
: 9	" 2	4	" 2	2	" 4	4	" 5	6	" 4	4	" 4	4	——	
3 : 4a	" 3	4	< 4	5	< 3	5	" 2	4	" 5	6	< 4	4	——	
: 5	" 6	9	> 4	6	> 3	4	" 6	8	" 4	4	> 5	8	" 4	7
: 6	——		" 3	4	" 3	6	" 6	8	" 3	4	" 5	6	——	
: 7	" 1	2	" 7	8	" 4	8	" 5	5	" 5	7	" 8	11	" 4	4
: 8	" 1	2	" 3	5	" 3	6	" 2	4	" 3	4	" 4	5	" 2	2
: 9	" 1	1	" 3	6	——		" 2	3	" 2	2	" 6	8	" 3	4
4a : 5	" 4	7	" 2	3	" 2	4	" 3	3	" 2	4	" 1	2	——	
: 6	" 1	2	" 1	2	< 4	6	" 6	8	" 2	3	" 3	4	——	
: 7	" 5	6	" 4	6	> 5	7	" 3	3	" 2	2	" 4	8	——	
: 8	< 3	4	" 1	2	" 5	8	" 4	4	" 3	4	" 3	4	" 2	2
: 9	> 2	3	" 1	2	——		" 2	3	" 2	3	" 2	4	——	
4b : 5	——		< 2	2	——		" 2	3	" 2	3	" 2	4	——	
: 6	——		——		——		" 3	4	" 2	4	" 2	3	——	
: 7	——		——		" 2	3	< 2	3	< 2	3	" 4	4	——	
: 8	" 1	2	——		< 1	2	> 2	3	> 2	3	< 2	3	——	
: 9	——		——		——		" 2	3	" 2	3	> 2	4	——	
5 : 6	" 2	3	" 2	2	> 3	4	" 2	3	——		" 2	2	——	
: 7	" 5	8	> 4	5	" 2	3	" 5	6	" 3	4	" 7	7	" 3	4
: 8	" 1	2	< 3	4	" 3	5	< 5	8	< 1	2	" 2	3	" 2	2
: 9	" 2	4	> 2	4	" 1	2	" 3	3	> 2	3	" 6	8	" 5	6
6 : 7	——		" 1	2	" 2	2	> 2	3	" 2	3	" 3	4	" 2	2
: 8	——		——		" 2	2	" 3	4	" 2	3	" 4	4	——	
: 9	——		——		" 3	4	" 2	3	" 2	3	" 3	6	——	
7 : 8	——		" 2	4	——		" 2	3	" 2	3	" 4	6	——	
: 9	——		< 2	2	——		" 3	6	< 2	3	" 4	7	——	
8 : 9	——		——		——		" 4	8	> 2	4	" 4	5	——	

(2) There are a few exceptions to this rule. To understand them we must ask at once—taking the confirmatory evidence of Series II for granted—for the *reason of the reversal of the illusion*, in its transference from optics to haptics. That reason is given in terms of introspection by the reagents. All alike asserted that the points in the filled line were sensed as "bunched" or "crowded" together. The space between two points can be fairly accurately apprehended—we are not speaking, of course, of objective accuracy—but a space which is more or less filled "shrinks" together, and may be reduced to what are comparatively very small proportions. Doubtless, for the majority of the subjects, the first judgment was more influenced by visualization than was the second. But this is

an error common to almost all cutaneous experiments. And, though it may have aided the reversal of the illusion, it certainly could not have produced it. Moreover, the reagent *Ti.* has been able, by practice, pretty completely to separate the visual from the cutaneous judgment,[1] and the reversed illusion holds quite strongly in his case. The "bunching" or "crowding" is psychophysically explicable in terms of irradiation.

(3) Now for the exceptions. (*a*) $2 < 4a$ for *Ha.* Reference to the scheme will show that $4a$ may be regarded as an open line, doubly bounded at either extremity. This double bounding would make the point-impressions especially intensive. Now it proved to be a constant error in these experiments—one which evidenced itself in the practice series, in which experimenter was being educated as well as experimentee—that *increased intensity of pressure meant a judgment of increased length of line.* We did not attempt any quantitative evaluation of this error; the error itself was eliminated by the acquisition of facility and accuracy in the handling of the blocks. But we suggest that the error, in a modified form, may account for these exceptional judgments. (*b*) $3 < 4a$ for *Ha.*, *H.* and *T.* This is, again, easily accounted for. 3 is a filled line; $4a$ may be sensed as a doubly bounded open line. When this is the case, the judgment $<$ will follow, in terms of the cutaneous illusion. (*c*) $4a < 6$ for *Ha.* This we can only explain by supposing that the dots in the middle of 6 were crowded together in sensation, the terminal points being thus left free. (*d*) $4a < 8$ for *B.* Again, we have possibly a similar explanation. The two 4's of 8 are crowded, leaving the centre space free; $4a$ is more irregularly filled for sensation. Introspection gave a confirmatory result in both these cases. (*e*) $4b < 5$ for *Ha.* The two blocks are so similar, that any accidental and variable factor may have conditioned this judgment. (*f*) $4b < 7$ for *O.* and *Ol.* Here, again, the blocks are of like patterns. Perhaps the central dots of 7 were massed, leaving the ends free. (*g*) $4b < 8$ for *H.* and *T.*; *cf.* (*d*) above. (*h*) $5 < 6$ for *Ha.* The former is more uniformly filled. (*i*) $5 < 8$ for *Ha.*, *O.* and *Ol.*; *cf.* (*d*) and (*g*) above. (*k*) $5 < 9$ for *O.* This cannot be explained by reference to the blocks. (*l*) $7 < 9$ for *Ha.* and *Ol.* Nor can this.

We would call attention to the facts: (i) that these are very few exceptions, *when the fewness of the experiments in*

[1] Proof of this statement will be advanced later, in articles by Dr. M. F. Washburn and Mr. W. B. Pillsbury, dealing respectively with the influence of the visual idea upon cutaneous space judgments, and upon cutaneous localization.

general is borne in mind; (ii) that most of them are explicable in terms of the illusion itself; and (iii) that they are by no means co-ordinate. For the discrimination of certain of the blocks, pretty thorough *practice* and very constant *attention* are necessary. Judgment becomes at once uncertain if *fatigue* has begun to set in. Not only is an accidental increase of pressure liable to be interpreted as an increase of length, but *vagueness or insecurity of judgment* (due to exhaustion, inattention, etc.) was also found to be so interpreted. Yet, in face of the fewness of the experiments and of all these sources of error, we see that *2 is judged greater than every other block*, except in one set of judgments from one reagent, with the misleading block 4*a*. We may remark, also, that the evidence from the experiments is stronger than that from the table; since there occurred cases—not many, it is true—in which the judgment contrary to $>$ is not $<$, but $=$. Such cases have not been specially treated by us.

Series II.

In the second series of experiments a line was compared with a point-distance. The line was the impression obtained from the application of a strip of hard rubber, $\frac{1}{100}$ inch in thickness. The point-distance was given with the æsthesiometer figured on p. 422; the bulb being left unemployed, and the pressure regulated by practice. This was necessary, since we had no rubber strips, but only points, attached to the shaft of the instrument. The method followed was that of right and wrong cases. Here, again, the experiments, though not numerous, speak with complete decisiveness for the reversal of the optical illusion.

The first column of the table gives the reagent; the second, the length of the filled line, in mm.; the third the point-distances with which it was compared—the difference between each point-distance and its next successor being 1 mm.; the

Table II. Unit = 1 mm.

R	Line.	Limits of Pt.-distances.	*n*.	Equivalence.
B.	28	28—23	15. 20. 20. 20. 40. 40.	Between 24 and 23
Ha.	20	20—15	30. 15. 35. 30. 35. 100.	15
T.	28	28—24	20 throughout.	Between 25 and 24
O.	28	28—23	17. 20.	" 24 " 23
Ol.	28	28	20 throughout.	" 23 " 22

fourth, the number (n) of experiments made with each point-distance; the fifth the point-distance which proved to be subjectively equal to the constant line-stimulus.

I. e., an open space of 24 mm. is equal to a filled line of 28 mm., and one of 15 to a filled line of 20. The different values of the line were taken owing to the fact that the limen of twoness for *B.*, *T.*, *O.*, and *Ol.* lay considerably higher than for *Ha.*

Table III shows the results of lines 2 and 5 of the above Table more in detail, and proves the point made just now—that the experiments speak very decidedly for the reversal of the optical illusion.

TABLE III *a*.

Reagent *Ha*. Rubber line = 20 mm.		
Point Distance.	Judgment.	Per Cent.
20	>	88
19	>	83
18	>	85
17	>	75
16	>	80
15	=	88

TABLE III *b*.

Reagent *Ol*. Rubber line = 28 mm.		
Point Distance.	Judgment.	Per Cent.
28	>	100
27	>	97.5
26	>	90
25	>	90
24	>	77.5
23	>	77.5
22	<	72.5

Further experiments might still further regularise the per cents.; they could hardly do more.

Conclusion. Literature.—We think the conclusion to be pretty obvious, that for the resting skin a filled line is shorter than an open space objectively equal to it. We have already suggested an explanation of this fact, in terms of irradiation, and specially directed visual association.

It has been asserted, quite recently, by Mr. Dresslar, that the illusion for touch is identical with that for sight. We would offer the following remarks: (*a*) In Dresslar's experiments it was not an open space that was compared with a filled, but a uniformly filled space (surface of a smooth card) which was compared with a discontinuously filled space (punctured card). It will be necessary to make experiments, both on active and passive touch, in this way: that a really open space be compared with a discontinuously filled

space. Till this has been done, the work of this experimenter must remain equivocal. (*b*) In active touch, the deeper lying sensibilities are involved to a much greater extent, and much more definitely from the qualitative point of view, than in our own experiments. We find no reference to this fact in Dresslar's introduction. (*c*) Whether we experiment with active or passive touch, the perception of movement is implied, and this is of itself amply sufficient to arouse the visual analogy. It seems hardly credible that Dresslar should not have come upon the visualization error in the course of his investigation. But we have not found any reference to it in his article. (*d*) Even for touch, as distinguished from pressure, there is evidence against Dresslar's results. James (Principles, II, p. 250—wrongly quoted by Dresslar as 242) declares that if the finger-tip be moved over a smooth and punctured card surface, the distances being objectively equal, the *filled* (*i. e.*, punctured) *space is shorter.* Loeb (Pflüger's Arch., XLI, p. 122—quoted by Dresslar as 121), it is true, found that an unevenly coated wire, drawn between finger and thumb, appeared longer than a smooth thread of equal length but somewhat less diameter, drawn at the same velocity. Loeb, however, calls especial attention to the effect of friction in this case. While therefore, his conclusion so far confirms that of Dresslar, the two experiments are not strictly comparable, nor is Loeb's at all exact. James is characteristically deficient in his description of his own experiments, but, so far as these are reliable, they stand in direct contradiction to Dresslar's. (*e*) A confirmation of our own results for the resting skin will be found in James' *Principles*, II, pp. 141, 142. The experiment cited is, however, very rough, and no numerical determinations are given. (*f.*) Dr. Nichols also supplies confirmation in his book, *Our Notions of Number and Space*, pp. 97, 105, 106, etc. . . . . We believe that this investigation, as well as that of Mr. Dresslar, must be very carefully scrutinized and tested, before its results can be accepted. But this is not the place to enter upon a general criticism.

So far as it goes, our own conclusion, that for the resting skin the filled line is shorter, distinctly supports the theory that the key to the corresponding optical illusion is to be looked for in movement. It will be interesting to see whether more accurate experiments than those quoted upon active and passive touch confirm this view, or point to the necessity of its modification.

[Both of the above sets of experiments were well under way before Mr. Dresslar's paper appeared. Dr. Nichols' book, received by the *Philosophical Review*, August 4, was not seen till after their conclusion.—E. B. T.]

NOTE TO STUDY NO. V.

1. Certain correspondents, among whom is my friend Dr. Meumann, of Leipzig, have pointed out what they judge to be a defect in the Washburn aesthesiometer (see p. 422), and what must also be regarded as a defect in the very similar Jastrow model. It is this: that there is no guarantee of the simultaneity of the two impressions. I would urge that even if this be granted, the new instrument is better than the old, for it at least ensures constancy of pressure, which that did not. But I think that more can be said in its defence. Its form makes it easier to handle ; and pressure made by it can be more readily controlled as regards the time factor, the attention not being distracted by the necessity of pressure regulation. And it certainly does not lie in wait for the experimenter with a constant error, as the sensibilometer does. If the skin, in the place worked on, is perfectly flat or of symmetrical curvature, the bulb might with advantage be held in a fixed support, and the part played by the hand be confined to that of regulating the time of impression and of release from stimulation. But where this is not the case, regulation of simultaneity by hand seems desirable. I do not know of any other control than those of the vision of the experimenter, and introspection of the experimentee. Of course the rubber points could be made to pass through the bar that holds them, and their length as regards one another be regulated by the skin curvature in the experimental series; but this alteration would introduce one of the faults of the sliding-scale form of the instrument—and would not the controls, after all, be then precisely what they are now?

2. Dr. E W. Scripture and myself have devised an improved arm-rest for the new model kinesimeter. Cuts of this and of the instrument itself will appear in the next number of the JOURNAL.

E. B. T.